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EFFECTS OF INDUSTRIAL EXHALATIONS ON THE SOIL BIOLOGY OF SPRUCE GROWTHS IN THE KRUSNA HORA MOUNTAINS
[Vliv prunyslobych exhalatu na pudni zivenu smrkovych porostu Krusnvch hor]

by

A. Sobotka

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Introduction

The Krusna Hora Mountains rise steeply from the Ohre valley and the Mostcko-Chomutov coal basin. A peculiarity of this mountain range is that it has no promontory. The forest growths in the area are often damaged by frost, snow and wind, and the weakened growths are then attacked by harmful insects, particularly by bark beetles.

It must be emphasized that poor soils are limited to relatively small areas. The Krusna Hora forests are heavily damaged and destroyed by exhalations from chemical and other industrial plants. This damage started sporadically already in the eighteenth century, and reached the highest intensity at the present time. Industry has an unfavorable effect, especially on forest water management, primarily on the sources of drinking water and the water supply. For this reason,

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forest conservation and forest management are particularly important in this region.

The goal of the study was to determine whether the harmful industrial atmosphere has also an effect on the forest soil, and if that is indeed the case, to determine how this effect manifests itself in the biological structure of the soil. The study is also a contribution to knowledge about the biotic component of the soil.

Method and Working Procedure

To study the effect of industrial exhalations on soil biology, we must carry out a quantitative and qualitative analysis of the biotic soil component in undamaged and damaged growths. A prerequisite for this analysis are identical natural conditions in both groups of growths. For this reason, maturing and mature spruce growths of the same type were selected in a region so far undamaged by industrial gas and smoke (the area in the vicinity of the St. Sebastian Mountain), and medium or heavily damaged growths (in the Vilejsov and the Komari Vizka region). The growths were selected on the basis of the research which was carried out by workers of the forestry management and gamekeeping institute at Zbraslav-Strnada in previous years. All growths which were studied belonged to the same forest type (Fago-Piceetum typicum), and the same type of soil (reddish forest soil).

The working procedure in individual sectors is described briefly in the study of isolated testing sites. The usual methods which have already been described earlier (for example, in the final report "Microbiological Research of Forest Soils by Forest Types," Parts II and III, VULHM Zbraslav-Strnada, 1961). were used in terrain and laboratory work.

The Study

In this part, every test area is characterized separately.

Test area number 12 -- is an undamaged growth. The test area is in the region of the Chomutov forest plant, in the Straz forest, growth number 21n. The growth is on a plateau 850 m above sea level. It is a two-layer growth which extends over 26.7 ha. The first layer is pure 95-year-old spruce, trunk width 0.8, bonitation 7. The second layer is outside the test area. The geological foundation is gneiss. The soil type is rusty forest soil (according to Pelisek). A 10-cm-high layer forms horizon A_0, horizon A_1 is a 9 cm layer, and horizon B begins 19 cm below the surface. Most nutritive roots extend to a depth of 35 cm. (The chemical characteristics of the soil are given in Table I.)

Detailed measurements and analyses were made in 1957 (4.16, 6.20, 9.24, 11.12), in 1958 (5.21, 7.4, 9.3, 10.30, 11.27), in 1959 (4.8, 5.25, 6.22, 7. 15, 9.2, 9.30, 11.11), and in 1960 (4.28, 6.14, 8.30). The following were determined: the temperature of the air 10 cm above the surface of the soil and the temperature 3 to 10 cm below the surface, the percentage of water content both in a fresh soil sample at a depth of 2-5 cm and in a layer at a depth of 5-25 cm after it was sieved through a 2 cm sieve, the active acidity in both layers which were mentioned, the biological activity, ammonation capacity, nitrification power, the percent representation of aerobic and anaerobic bacteria, fungi, and sporulating bacteria, the quantitative and qualitative proportion of phytomyteces (live and shells) testacea (live, shells and cysts) flagellata, infusoria, whirligigs, worms, and all remaining species, the quantitative and qualitative proportion of mezoedathonts, worms, scorpions, spiders, mites, centipedes, millipedes, bugs, springtails, maggots, winged insects, Psocoptera, aphides, forest bugs (including larva), winged bugs (including larva), and the symbiotic relationships among fungi and nutritive roots in the most prevalent trees.

On the test site, and, altogether, on 1 ha, there were 1184 spruces and 192 young rowan trees. In the year 1963, Xerocomus badius (Fr.)-Kuhn., Clavaria aurea Fr. grew in the area. Altogether, 29 spruces and 5 young rowan trees were selected for the complete, detailed analysis, and also 17 parts of the root system in old spruces.

The nutritive roots of the spruces aged up to 8 years which were attacked were divided into four distinct forms (1 SN, 2 SN, 3 SN, 7 SN); all the trees had five distinct nutritive root forms in topsoil (1 H, 2 H, 3 H, 4 H, 7 H), and three distinct shapes in mineral soil (2 MP, 4 MP, 5 MP)*. [See footnote on next page]

The average height of the rowan seedlings was 7.5 cm (the minimum and maximum heights were 4 and 17 cm), the number of branches were 1-8, the neck was 1.5-1 mm thick, the length of the tap root was 4-16 cm, there were 1-13 second order roots 1-11 cm long, 3-41 third order roots 0.5-2 cm long. The total number of nutritive fine roots varied between 23 to 194. The nutritive fine roots of rowans which were attacked had two forms, both without a fungus symbiont.

Area number 14, is an undamaged growth. The test area is in the same forest as area number 12, in growth 7g. According to the forestry layout, it is a pure 60-year-old spruce grove. The trunk width is 0.9, average height is 12,m, bonitation is 7. The growth was planted, has been neglected, and is spotty in places. The elevation is 810 m above sea level, and it slopes gently to the West. The geological foundation is gneiss. The type of soil is rusty forest soil. Horizon A_0 extends to a depth of 6 cm, horizon A_1 to a depth of 18 cm, horizon B_1 to 28 cm, and horizon B_2 starts at 28 cm. Most nutritive fine roots reach a depth of 30 cm, however, growth is only dense in the layer up to 16 cm

[Footnote * to second paragraph on page 4]

* The forms and shapes of the nutritive spruce roots in the Krusna Hora region are:

1. (1 SN) light brown, with lighter ends, medium thickness, average length, separate. The 6-9 μ mantle is developed only in spots, sometimes the Hartig net is absent or reaches the endodermis.
2. (2 SN) dark brown, medium thickness, separate and branched; the mantle is 10 μ wide, compact, and goes very deep into the bark parenchyma.
3. (3 SN) yellow to orange, average thickness and thicker, separate. The mantle is 20 μ wide. The Hartig net is only in the first layer of the core parenchyma. Fibers protrude from the mantle into the environment.
4. (1 H) light brown to orange, medium thickness and thicker, short, separate and tufts. The composition of the mycorrhiza is identical to form 3 SN.
5. (2 H) dark brown, medium thick to thick, of medium length, mostly clusters. The mantle is smooth, 6-15 μ wide, with fine cells. The Hartig net covers three-thirds of the parenchyma width. The mantle has sometimes fibers of another fungus.
6. (3 H) black, rather thin, short to medium length. The mantle is not developed. The Hartig net is clearly developed and reaches the endodermis, the fibers protrude from it directly into the environment.
7. (4 H) light brown, thick, of medium length, separate and interwoven. The mantle is only 6 μ wide and compact. The Hartig net is complete, and reaches the endodermis. Isolated intracellular infections.
8. (5 H) whitish, thick, short and long, separate. The smooth mantle is 4 wide. The Hartig net is powerful in the entire parenchyma layer.
9. (7 H) reddish brown, thin, of medium length, in tufts. Without a mantle, the Hartig net reaches the endodermis.
10. (1 MP) brown, thin to medium thick, with yellow point, separate. The fibers protrude from the very thin mantle into the environment. The Hartig net goes very deep to the endodermis.
11. (2 MP) black, thin to medium thick, rough on the surface, separate, interwoven and tufts. The fine root has no mantle, and the fibers grow from the Hartig net directly into the environment. Frequent intracellular infection.
12. (3 MP) black, medium thick, average to long, separate and interwoven. Many fibers protrude from the 30-μ-wide mantle into the environment. The Hartig net sometimes spreads unevenly in the parenchyma; at other times, it is spread in the entire parenchyma.
13. (4 MP) orange, short, thick, fine roots in tufts. The smooth mantle is 25 μ wide. The Hartig net goes very deep.
14. (5 MP) white, thick, medium to long, separate and interwoven. Isolated fibers protrude from the 20-30-μ-side mantle into the environment. The Hartig net reaches half the depth of the bark.
15. (6 MP) yellowish brown with white points, very thick, tufts. The mantle is up to 60 μ wide, regular pseudoparenchyma rough on the surface. The Hartig net is only in the first and second parenchyma layers.

[End of footnote]

Detailed measurements and analyses were carried out on 4.8, 5.25, 6.22, 7.15, 9.2, 9.30, 11.11, 1959 and 4.28, 6.14, 8.30, 1960. All areas were

studied to the same extent and the results are given for area number 12.

There were 61 spruces on the test area. On 9.11.1963, propagating Boletus edulis ssp. bulbosus Fr. and profusely propagating Russala ochroleuca (Pers.) Fr. were discovered in the area. Altogether, 22 sectors of the root systems of old trees were selected for the detailed study.

The nutritive roots in topsoil had, as in area number 12, four distinct forms, and, in addition two other forms (6 H, 8 H), i.e. altogether six forms, in mineral soil two distinct forms (2 MP, 4 MP) agreed with area number 12, and there was an additional form (6 MP), altogether three forms.

Area number 13 is a growth with medium damage. The test area is in the Horni Litvinov forest plant region, in the Flaje forest, growth $168d_2$, in the Vilejsov locality. The growth is a pure 110-year-old spruce growth. Trunk width, 0.7, average height, 20 m. The geological foundation is gneiss; the type of soil is rusty forest soil. According to exploratory boring, the A_0 horixon is 7 cm thick, A_1 is 1 cm, A_2 is 6 cm, and horizon B begins 14 cm below the surface. The nutritive fine rooos occur most frequently up to a depth of 15 cm. The chemical analysis which was taken from another study and therefore has a different arrangement than in areas number 12 and 14, is given with the remaining analyses in Table I.

Detailed measurements and analyses were made on 4.16, 6.20, 9.24, 11.12, 1957, 5.21, 7.4, 9.3, 10.30, 11.27, 1958, 4.8, 5.25., 6.22., 7.15.,9.2,, 9.30., 11.11.1959, 4.28., 6.14.,1960, and 11.19.1963.

The test area contained 42 old spruces, 20 spruce seedlings, 2-7 years old, and 5 4-7-year-old rowan seedlings, which, when calculated per 1 ha, gives 320 spruce and 80 rowan seedlings. Altog ether 19 spruce and 5 rowan seedlings and 19 parts of the root system of old trees in topsoil and mineral soil were selected for detailed analysis.

Table I

Results of chemical analyses of soil samples from the test areas

Půdní vrstva a	Výměnná kyselost pH b	Obsah C % c	Vesnety N % d	Citrátový výluh e			
				K_2O	CaO	MgO	P_2O_5
				v mg/1 kg půdy f			
g Plocha č. 12							
horizon A_0	3,3	34,95	1,67	204	507	86	166
horizon $A_1 B$	4,4	2,30	0,30	20	179	43	63
g Plocha č. 14							
h vrstva 0—16 cm	3,8	21,35	1,38	200	238	43	240
h vrstva 16-30 cm	4,7	1,90	0,25	17	149	21	66
g Plocha č. 13							
horizon A_0	3,3	—	2,81	80	160	30	103
horizon A_1	3,2	—	—	45	231	97	115
horizon A_2	3,6	—	—	118	296	125	121
g Plocha č. 19							
horizont A_0	3,2	—	1,31	85	352	185	101
horizont A_1	3,2	—	—	97	264	78	78
horizont A_2	3,5	—	—	91	197	103	66

Key:
a. soil layer
b. exhange acidity, pH
c. C content, %
d. total N, %
e. citrate extract
f. in mg/ 1 kg soil
g. area number...
h. layer

In top soil, the old trees had nutritive roots which belonged to six distinct forms (1 H, 2 H, 3 H, 4 H, 5 H, 7 H) and , in addition to this, two abnormally developed forms (2 $\overline{H}$, 5 $\overline{H}$), in mineral soil there were six distinct forms (1 MP, 2 MP, 3 MP, 4 MP, 5 MP, 6 MP), and, in addition to these, one abnormal form (L $M\bar{P}$). The nutritive roots of seedlings belong to three distinct forms (1 SH, 2 SH, 3 SH).

The spruce seedlings were 6-10 cm high, the neck was 1.5-2 mm, the needles were a deep green, the tap root was 4-11 cm long, with 2-19 long roots, 1-3 cm long, and 15-75 nutritive fine roots.

The nutritive fine roots of the rowan were classified as in area number 12. They had a similar morphology and anatomical findings. The exception were the intracellular fibers in the second layer in the bark parenchyma in the yellow-white nutritive fine roots. The fibers were 3.5 μ wide, linked and interwoven. The rowan seedlings were 8-24 cm high, the neck was 2-4 mm, the tap root was 6-25 cm long, with 12-51 long roots (total length 28-522 cm) and 59-522 nutritive fine roots.

Area number 19 is a heavily damaged grove. The test area is near the forest plant Dubi, the Krupka forest, growth number 14h, in the Komari Vizka locality. The pure spruce grove is 40 years old, trunk width 0.8, average height 13.5 m. The growth has been neglected; in spots it is too thick with broken trees which have not been attacked. The elevation is 810 m above sea level, and it slants 3° South. The geological foundation is siliceous porphyry according to exploratory boring, the soil is rusty forest soil. Horizon A_0 is a 9-cm-thick layer, horizon A_1 is 8 cm thick, horizon A_2 is 11 cm, horizon B is 7 cm high, and 35 cm below the surface is bedrock. Boulders make up almost the entire profile. The greater part of the nutritive fine roots reaches a depth of 28 cm.

The test area contained 91 old spruces. On 11.19.1963, procreating Russula ochroleuca Fr. were detected in the area. Altogether 13 parts from the root system of 13 spruces were selected in stages for the detailed analysis.

The nutritive fine roots in topsoil belong to three distinct forms (1 H, 3 H, 6 H) and three abnormally developed shapes (2 $\overline{H}$, 4 $\overline{H}$, 7 $\overline{H}$) and in mineral soil, have two distinct forms (3 MP, 6 MP) and one deformed shape (1 $\overline{MP}$).

The detailed studies were carried out on 4.8., 5.25., 6.22., 7.15., 9.2., 9.30., 11.11.1955, 4.27., 6.14., 8.30.1960, and 11.10.1963.

Results of the Studies

Comparison of the old spruce growth areas

Area number 12 is a pure, undamaged spruce grove which is 95 years old. Area number 13 is a pure, medium damaged 110-year-old spruce grove, which was damaged by industrial exhalations.

Ecological factors, biochemical processes, bacteria and fungi

The individual soil samples which were taken on area number 12 always contained more than 30% water. The active acidity of the soil fluctuated between a minimum of 4.2 and a maximum of 2.9 pH. The minimum total nitrogen content was 1.596 mg, and the maximum content, 4.118 mg/1 kg of dry soil.

The average yearly CO_2 production was, in the year 1957, 75 mg/1 kg of dry soil, in the year 1958, 96 mg, in the year 1959, 62 mg, and in the year 1960, 100 mg. The ammonation capacities fluctuated around the average yearly values: in 1957, 41.0, in 1958, 62.0, in 1959, 35.3, and in 1960, 68.7 mg NH_3/N per 1 kg of dry soil.

The ratio of aerobic bacteria to anaerobic bacteria and fungi fluctuated from 24.6 to 98.3%. The relative occurrence of anaerobic bacteria fluctuated between 0.5 to 25.5%. Among fungi, the most frequently encountered types were of the Penicillium genus, to a lesser extent, the Mucor genus, and, to a very slight extent, the Zygorrhynchus, Rhizopus, Trichoderma, and Cladosporium genus, etc.

Analogous studies made on area number 13 concluded with the following results: the soil samples always contained more than 35% water. The minimum soil acitidy was 4.5 pH and the maximum acidity, 3.1 pH. The total nitrogen

content fluctuated between a minimum of 1.722 and a maximum of 5.841 g/kg of soil. The yearly average respiratory capacity dropped from 123.4 mg in 1957 to 84.6 mg in 1959. The ammonation capacity varied between wide limits, from 18.3 to 90.3 mg NH_3 N/kg of dry soil. The yearly averages were: in 1957 55.5, in 1958 76.0, in 1959 44.6, in 1960 69.0 mg.

Aerobic bacteria dominated fungi in the ratio 3:1 to 9:1. Anaerobic bacteria (relative to aerobic bacteria and fungi) were most frequent in the years 1959-1960. In both previous years, their proportional representation was weak. Among fungi, various types of the Penicillium genus predominated, sterile mycelia were also numerous. The Zygorrhunchus, Mucor, Rhizopus, and Trichoderma genus, etc. occurred in smaller numbers.

Alga, Protozoa (see Table II)

All types of alga and protozoa which occur in the topsoil of mountainous spruce trees (for example, Brdy, Orlicke hory Mountains, etc.) are represented both quantitatively and qualitatively in the Krusna Hora on damaged spruce growth. Vaccinium mytillus and Vitis idaca have no essential effect on the composition of these groups of topsoil microedaphons. It was established in the medium damaged growth in test area number 13, that there is no substantial difference between it and the undamaged growth in test area number 12, in area number 13, the number of phycomycetes is larger than that in test area number 12, and the number of live flagellata and infusoria is also larger in area number 13.

Mezozooedaphon (see Table III)

In test area number 12, the average number of individuals per 100 cm^2 was 1921 (between the limits 1205-2894). The number of Collembola was relatively smaller, with the exception of a sample from a decaying stump. Samples that were taken from places with plant vegetation are quantitatively poorer in mezozooedaphons.

Moss and high layers of spruce falloff are proportionately quantitatively richer. Layers of spruce falloff higher than 5 cm are extremely poor, and springtails are always sufficiently numerous. The yearly counts do not fluctuate much, because the summer minimum which results from dryness in lower areas is here compensated by a decisive factor, the higher humidity. Seasonal differences are more apparent in the qualitative composition; there is a noticeable increase in Psocoptera and Diptera larva.

Table II

Quantitative and qualitative analysis of a part of the microedaphons, area number 12 (undamaged old spruce growths)

a Datum odběru	Rozsivky b		Krytenky c			d Bičíkovci	e Nálevníci	f Vířníci	g Hlístice
	živé h	schránky i	živé h	schránky i	cysty j				
1957									
16. 4.	0	0	1094	2 765	0	2784	2054	422	346
20. 6.	0	19	2592	29 856	115	2752	2208	365	422
24. 9.	0	32	5984	17 760	224	13760	2080	576	384
12. 11.	0	32	2512	25 984	32	8000	448	288	480
1958									
21. 5.	0	0	2688	28 192	64	3200	1280	96	192
4. 7.	0	0	224	14 752	64	1312	544	32	128
3. 9.	0	0	1536	16 703	84	1440	736	0	128
30. 10.	0	0	1888	24 832	0	5440	1600	32	192
27. 11.	0	0	1536	25 600	0	1600	960	128	96
1959									
25. 5.	0	0	1600	19 904	256	1280	640	0	320
22. 6.	0	0	2016	40 032	224	6880	1280	96	352
2. 9.	0	0	1344	23 136	96	7040	1440	96	192
11. 11.	0	32	1088	20 382	192	5760	640	0	128
1960									
14. 6.	32	64	1440	22 848	128	2560	1440	256	96

Key:
a. date of sample
b. phycomycetes
c testacea
d. flagellata
e. infusoria
f. whirligigs
g. worms
h. live
i. shells
j. cysts

Area number 13 is essentially the same as area number 12. The qualitative composition is: almost 90% mites , approximately 10% Collembola (in extreme cases 20%) and the remaining mezozooedaphons are represented in very small numbers.

Nutritive fine roots of trees

In the undamaged growth (area number 12), the spruce seedlings had four distinct forms of nutritive roots, old spruces in topsoil five forms, and in mineral soil also five distinct forms. All nutritive fine roots werer mycorrhizal, except one form in which there were a few fine roots without a symbiont. The rowan turned out to be a tree with autotrophic nourishment.

In the growth on test area number 13, which was moderately damaged by exhalations, the nutritive fine roots of spruce seedlings belonged to three distinct ectotrophic mycorrhiza forms. Old trees had six forms in topsoil and the same number in the mineral layer; however, these were not always distinct normal forms. In one shape (2 H) in addition to the fine roots which had normal shapes, there were also deformed fine roots (crooked, conical) which were not uniformly thick around the entire length. The situation was similar in the next two forms (5 H, 1 MP). The differences detected through microscopic analysis, were often in the abnormal roots and elsewhere; the mantle was unusually developed. It was incomplete, tuft-like, and exceptionally thin. Often the mantle was missing and the fungus fibers grew directly out of the Hartig net into the fine root environment The mantle often peeled off. The forms which deviate from the norm have not been found in other mountainous regions (Brdy, Orlicke hory mountains, the High Tatras) if we ignore the peeling of the mantle which occurs rather frequently in mountains.

Table III

Mezozooedaphons, area number 12 (undamaged, old spruce growth)

a Datum odběru	b Prostředí	c Absolutní počet	d Přepočteno na 100 cm²	e Pavouci	Oribatoidei	Roztoči b: nymfy g	Roztoči b: ostatní h	Myriopoda	Protura	Collembola	i Pisivky	j Mšice	k Brouci včetně larev	l Diptera včetně larev
1959														
25. 5.	*Vaccinium*	475	2375	0	34,31	56,84	1,05	1,89	0,84	4,84	0	0	0,21	0
	spruce falloff	535	2675	0	16,07	74,76	1,68	0,18	0,37	6,91	0	0	0	0
	moss from stump	987	—	0	62,41	30,39	3,24	0	0,10	3,76	0	0	0,10	0
	stump	347	—	0	53,84	14,40	2,30	0	0	29,10	0	0	0,28	0
22. 6.	moss	339	1695	0	37,16	53,98	2,94	0	0,58	4,71	0	0	0,58	0
	grass	312	1560	0	14,10	64,10	8,97	0	0	12,50	0	0,32	0	0
15. 7.	grass	825	1650	0,12	15,87	72,72	1,93	0,12	0,60	8,48	0	0,12	0	0
	spruce falloff	218	2890	0	28,89	66,55	1,03	0	0,17	9,34	0	0	0	0
2. 9.	moss, grass	279	1395	0	22,93	71,68	2,86	0	0	1,07	0	0	1,06	0,35
	moss	1447	2894	0	19,35	69,10	2,62	0,48	0	8,43	0	0	0	0
30. 9.	moss, grass	285	1425	0	25,61	52,63	8,42	2,10	0,35	10,17	0	0,35	0,35	0
	Vaccinium	951	1902	0	29,54	63,09	2,73	0	0,10	3,89	0,21	0,42	0	0
11. 11.	spruce falloff	944	1888	0	21,08	68,85	2,01	0	0	7,30	0,53	0	0,21	0
	spruce falloff	640	1280	0	41,09	46,87	5,15	0,15	0	6,71	0	0	0	0
	Vaccinium	243	1215	0	30,45	53,49	6,99	0	0	7,81	0,82	0	0	0,41
	grass	492	2460	0,20	24,59	68,49	3,65	0,20	0	2,43	0,20	0	0	0

Key:
a. date when sampled
b. environment
c. absolute number
d. recalculated per 100 cm^2
e. spiders
f. mites
g. nymphs
h. all remaining ones
i. Psocoptera
j. aphides
k. bugs including larva
l. Diptera including larva

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Comparison of maturing spruce growth areas

Area number 14 is a pure undamaged spruce growth which is 60 years old. Area number 19 is a heavily damaged, pure 40-year-old spruce growth.

Ecological factors, biochemical characterization, bacteria, fungi

The water content in the soil samples fluctuated between 26 to 40%. The active soil acidity throughout the year over a period of several years fluctuated moderately between a minimum of 4.5 pH and a maximum of 3.2 pH. The minimum total nitrogen content was 1.120 g, and the maximum 3.915 g per 1 kg of dry soil. The average yearly values of the carbon dioxide produced fluctuated considerably over a number of years; the minimum was above 13.9 and the maximum was 173.8 mg CO_2 per 1 kg of dry soil. The ammonation capacity varied between the limits 21.1 to 56.0 mg NH_3/N per 1 kg of dry soil. Nitrogen nitrate was detected in measurable amounts only three times over a period of three years.

The number of aerobic bacteria was always larger than the number of fungi. The percent proportion of fungi and anaerobic bacteria fluctuated more than the proportion of aerobic bacteria. Types of the Penicillium genus which exceeded numerically other types from the Mucor, Zygorrhynchus, Cladosporium, Candida, Fusarium genus, etc. occured in small numbers.

In the damaged growth (area number 19), relatively small amounts of water were found in the samples, expecially in July, September, and October 1959 (11, 15, and 14%). However, in 1960, the average yearly water content was 29%. The area slopes to the south and the humidity is less favorable. The active soil acicity fluctuated between 4.7 to 3.2 pH. The total nitrogen content was relatively balanced during the samples in the range 1.386 to 3.964 g per 1 kg of soil. The biological activity fluctuated in the year 1959 in the range 14.77 to 66.7 mg CO_2 per 1 kg of dry soil; in 1960, the results were higher. The ammoniacal nitrogen content in the incubated samples was highest in 1960 (72.96 mg NH_3/N

per 1 kg of dry soil). The nitrogen nitrate content was negligible except in two cases (3.2 and 3.7 mg NO_3/N per 1 kg of dry soil).

There were always more aerobic bacteria than fungi. The ratio varied from 1.1:1 to 8:1. The number of fungi increased in dry periods. The number of anaerobic bacteria fluctuated heavily. In addition to the largest number of types from the Penicillium genus,and the large number of types from the Mucor genus, other types of genus were represented: Paecilomyces, Trichoderma, Cladosporium, less frequently Candida, Sporotrichum, Pullularia, Scopulariopsis and sterile mycelia. The physiological group of amylo bacteria were always detected.

Alga, protozoa (see Table IV)

Area number 14; the finding in the microedaphon group mentioned above corresponds to that in area number 12. Area number 19 corresponds to mountainous spruces in other regions. Here, a small number of phycomycetes was found, the finding was probably accidental. However, the number of flagellata and infusoria is considerably smaller (in comparison with area number 14).

Mezozooedaphon (see Table V)

It can also be said here that area number 14 basically agrees with area number 12. The number of individuals fluctuated between 1055 and 2802, and the balanced average was 1660. The larger number of Collembola agrees with previous findings in other regions, and is related to the poor location and possibly the high acidity in the environment. Area number 19 is characterized by a high proportion of mites and a relatively small proportional representation of other groups. Springtails represent less than 6%, the remaining groups are only fractions of a percent. Protura are almost completely absent. The number of Myriopoda and bugs including larva is also smaller. Diptera larva were detected only in a single case. Psocoptera are more frequent in the fall.

Nutritive fine roots

In both areas, we could only compare maturing spruce trees. In area number 14, 6 distinct forms were represented in topsoil, predominantly mycorrhizal, as in mineral soil, where there were five distinct forms. The fine nutritive roots in all forms corresponded to the findings from other mountainous regions. The variability in the intensity with where the symbiont mycelium penetrated the bark network of the nutritive fine roots is almost identical with the variability detected in other mountainous regions.

Table IV

Quantitative and qualitative analysis of a part of the microedaphon, area number 19 (heavily damaged spruce growth)

a Datum sběru	Rozsivky b		Krytonky c			Bičíkovci d	Nálevníci e	Vířníci f	Hlístice g
	živé h	schránky i	živé h	schránky i	cysty j				
1959									
25.5.	32	-	1312	23 548	-	1440	672	-	224
22.6.	--	32	1248	25 024	64	2720	840	128	352
15.7.	--	--	2432	22 560	256	2880	960	--	96
2.9.	--	--	1824	36 000	32	2880	416	896	--
30.9.	--	64	3200	38 112	320	5440	1120	64	256
11.11.	--	--	1184	38 816	352	1440	320	128	64
1960									
14.6.	--	-	2656	44 320	288	2880	960	96	32

Key:
a. date when sampled
b. phenomycetes
c. testacea
d. flagellata
e. infusoria
f. whirligigs
g. worms
h. live
i. shells
j. cysts

Table V

Mezozooedaphon, area number 19 (heavily damaged spruce growth)

Datum odběru [a]	Prostředí [b]	Absolutní počet [c]	Přepočet na 100 cm² [d]	Roztoči [e]			*Myriopoda*	*Protura*	*Collembola*	Červci [h]	*Thysanoptera*	Pisivky [i]	Pošvice [j]	Bronci včetně larev [k]	*Diptera* včetně larev [l]
				Oribatoidea	nymfy [f]	ostatní [g]									
1959															
25.5.	sm opad	315	630	27,93	49,84	5,39	0,63	–	15,87	0,31	–	–	–	–	–
	mech, tráva	378	756	38,62	52,91	1,85	0,79	0,26	5,29	–	–	–	–	0,26	–
	mech, tráva	222	444	35,58	45,04	5,85	0,45	–	13,06	–	–	–	–	–	–
	sm opad	715	1430	49,79	41,95	4,19	–	–	3,91	–	–	–	–	0,13	–
12.6.	sm opad	694	1388	35,30	54,75	3,89	–	–	6,05	–	–	–	–	–	–
	sm opad	131	655	50,38	35,11	2,29	1,52	–	9,92	–	–	–	0,78	–	–
	tráva	144	720	42,36	48,61	2,77	–	–	6,25	–	–	–	–	–	–
25.7.	tráva	683	1960	60,20	30,61	7,95	0,10	–	1,02	–	–	–	–	0,10	–
	sm opad	321	1605	26,16	62,30	3,73	0,31	–	7,16	–	–	–	0,31	–	–
2.9.	sm opad	223	1115	17,48	76,23	1,79	0,44	–	4,03	–	–	–	–	–	–
30.9.	tráva	701	1402	25,24	71,32	0,57	–	–	2,42	–	–	–	0,28	0,14	–
	mech	371	1855	30,72	61,99	3,50	–	–	2,96	–	–	0,26	0,53	–	–
11.11.	tráva	86	430	11,62	75,58	3,48	–	–	2,32	–	–	6,97	–	–	–
	tráva	402	804	24,32	67,16	3,48	–	–	2,98	–	0,24	–	0,24	0,99	0,49
	sm opad	227	454	16,29	74,68	3,52	–	–	3,96	–	–	0,44	–	0,88	–

Key:
a. date when sampled
b. environment
c. absolute count
d. recalculated per 100 cm^2
e. mites
f. nymphs
g. remaining
h. maggots
i. Psocoptera
j. forest bugs
k. bugs including larva
l. Diptera including larva

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In area number 19, the nutritive fine roots had six distinct forms in topsoil and three distinct forms in mineral soil. In addition to normally-shaped nutritive fine roots, many deformed roots similar to those in area number 13 were found. The greatest changes occur in the unstable form of the mantle and in the hypertrophic Hartig net.

Comparison of the Areas Studied

The relative average percent proportion of bacteria and fungi (%) in the areas were:

Area number	12	13	14	19
Aerobic bacteria	80	60	70	59
Anaerobic bacteria	8.5	26.5	15.5	14
Fungi	11.5	13.5	14.5	26
Bacilli	33	43	54	38

The survey shows clearly the dominance of aerobic bacteria. The relatively high proportion of fungi in area number 19 may be due to the relative dryness of the soil. When the type variability is evaluated, the types of the Penicillium and Mucor genus are dominant. The Mucor genus occurred in greater proportions in area number 19. According to the analysis of the soil samples, the maximum carbon and total nitrogen content was found in area 19. In the qualitative representation of a physiological group, larger numbers of aerobic bacteria and fungi were found in the damaged areas, especially in the most heavily damaged growth on area number 19. Among alga and protozoa, there is no difference between the soils of undamaged growths (number 12 and 14) and the soil of a medium damaged growth (number 13), on the contrary, the soil of a medium damaged growth is richer and of better quality. In the soil of the heavily damaged growth, there were one-third fewer flagellata and infusoria as compared to the soils of undamaged growths. The testacea were

not affected in the heavily damaged growth. The relation between the damaged and undamaged growths manifested itself in the mezozooedaphon as follows (according to the 47, 339 mezoedaphon pieces which were extracted):

The areas can be arranged in decreasing sequence as follows: number 12, 1921 pieces, number 13, 1844 pieces, number 14, 1616 pices, number 19, 1015 pieces. The relative proportion of springtails, Protura, Diptera, and other groups is smallest in area number 19 among all areas studied. The overwhelming majority of mezoedaphons in samples from this area consist of mites whose numbers fluctuated between 83.1 and 98.7%. The average proportion of mites was 93%, whereas area number 12, it was 91%, in area number 13, 89%, and in area number 14, only 85%. Area number 19 was free of spiders and the remaining groups occurred only sporadcially (Protura in two cases, maggots in one case, Thysanoptera in two, and Diptera in one out of the 17 samples). Only the Myriopoda, Psocoptera, Heteroptera and Colcoptera proportions were normal. In all samples from area number 19, the proportion of springtails was 5.6%, in area number 12, 6.5%, in area number 13, 10.4% and in area number 14, 12.6%. We may assume that the relatively smaller number of mezoedaphons and the elimination of sensitive components such as Protura is caused by unfavorable external factors.

When the nutritive fine roots of a spruce and rowan were evaluated in an undamaged area (number 12) and in a medium damaged area (number 13), no substantial difference was found among the seedlings. Among old spruce trees in medium and heavily damaged growths, in addition to the fine nutritive roots of various forms which developed normally, also other roots were found whose shapes were deformed, or other other roots which underwent changes, for example, roots with an unusually developed tuft-like or thin mantle, or roots without a mantle with an intensely developed Hartig net and frequent intracellular infections. The abnormalities which were mentioned increase in the direction of the surface

of the soil, and do not affect all trees uniformly. The variability in the nutritive fine roots can be attributed to changes in the physiological processes which go on in the trees, hence, also, to a change in the environment. Among rowan seedlings, the changes in the damaged areas which were very small and sporadic consisted of an intracellular infection of the parenchyma layer of the root.

Conclusion

Industrial gas exhalations caused heavy damage to forests in the Krusna Hora Mountains. To determine the effect of the polluted armosphere on soil biology, which is an indispensible component of forest soil fertility, extensive studies were carried out. For this purpose, undamaged, medium, and heavily damaged mature and maturing spruce growths were selected. The growths were of the same forest (Fago-Piceetum typicum) and soil type. Distinct test areas were selected in these growths. With the exception of macroedaphon, the ecological factors and the soil biology were studied for a period of several years.

The following conclusions were made: the number of aerobic and anaerobic bacteria, bacilli, and fungi is larger in medium and heavily damaged growth areas than in areas where the growths were not damaged by exhalations. A wider spectrum of fungus species was found in the heavily damaged growth. Among alga and protozoa, no essential difference was found between the damaged and undamaged areas. It was established that in the soil of the medium damaged growth, both groups occur more frequently. It is probable that the exhalations limit, in heavily damaged areas, the occurrence of infusoria and flagellata, since in these areas about one-third fewer of these were found than in undamaged areas. No effect of exhalations on testacea was observed.

A comparison of the mezoedaphon in all growths which were studied, shows that the effect of industrial exhalations was negative only on the heavily damaged area, both quantitatively and qualitatively. The average number of mezoedaphons

in this area is about one-half of that found in the richest undamaged soil. On the other hand, in medium damaged growth, the soil mezoedaphons (both the number and species composition) were entirely normal. It is possible that the decresse in the number of mezoedaphons and the absence of sensitive components, such as Protura, is caused by exhalations.

The nutritive fine roots of spruce seedlings were identical both in undamaged and damaged areas. The fine nutritive roots of all spruces give another picture. In medium and heavily damaged growths, in addition to normally shaped roots, various deformed fine roots were found, i.e. crooked, conical, and roots with various profiles. The mantle of the fungus partner was sometimes exceptionally thin or tuft-like and often altogether absent. The Hartig net was often hypertrophic and, if the mantle was missing, the fibers grew out above it directly into the environment. These deformations occurred more frequently near the surface of the soil. The abnormalities in the fine nutritive roots did not occur in all old spruce trees which were investigated. The great microtrophic capacity of the spruce was not reduced, but its abnormal formshows that the assimilation function, and thus also the normal physiological processes in the tree, were impaired. A detailed explanation of this fact requires further study.

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